Velocity vector: If $\langle x(t), y(t)\rangle$ is the position vector of a particle moving along a smooth curve in the plane, then at any time t, $<x'(t), y'(t)>$ is the particle's velocity vector. p. 548

Vertical line: In the Cartesian coordinate plane, a line parallel to the y-axis.

Viewing window: On a graphing calculator, the portion of the coordinate plane displayed on the screen.

Volume by slicing: A method for finding the volume of a solid by evaluating $\int_a^b A(x)\,dx$, where $A(x)$ (assumed integrable) is the solid cross section area at x. p. 404

Work: The definite integral of force times the distance over which the force is applied. p. 388

***x*-intercept:** The x-coordinate of the point where a curve intersects the x-axis. p. 5

***y*-intercept:** The y-coordinate of the point where a curve intersects the y-axis. p. 5

Zero of a function: A solution of the equation $f(x) = 0$ is a zero of the function f or a *root* of the equation.

Zero vector: The vector $\langle 0, 0\rangle$, which has zero length and no direction. p. 544

Answers to Odd-Numbered Questions

CHAPTER 1

Section 1.1

Quick Review 1.1

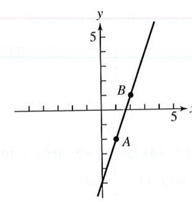
1. -2 **3.** -1 **5. (a)** Yes **(b)** No

7. $\sqrt{2}$ **9.** $y = \frac{4}{3}x - \frac{7}{3}$

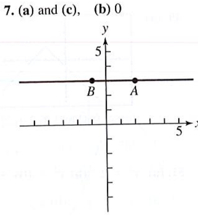
Exercises 1.1

1. $\Delta x = -2, \Delta y = -3$ **3.** $\Delta x = -5, \Delta y = 0$

5. (a) and **(c)**, **(b)** 3



7. (a) and **(c)**, **(b)** 0



9. $x = 3; y = 2$ **11.** $x = 0; y = -\sqrt{2}$ **13.** $y = 1(x - 1) + 1$

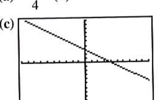
15. $y = 2(x - 0) + 3$ **17.** $y = 3x - 2$

19. $y = -\frac{1}{2}x - 3$ **21.** $3x - 2y = 0$

23. $x = -2$ **25.** $y = \frac{5}{2}x$

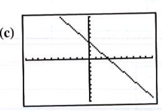
27. (a) $-\frac{3}{4}$ **(b)** 3

(c)



[−10, 10] by [−10, 10]

29. (a) $-\frac{4}{3}$ **(b)** 4 **(c)**



[−10, 10] by [−10, 10]

31. (a) $y = -x$ **(b)** $y = x$ **33. (a)** $x = -2$ **(b)** $y = 4$

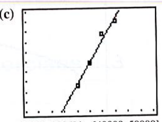
35. $m = \frac{7}{2}, b = -\frac{3}{2}$ **37.** $y = -1$

39. $y = 1(x - 3) + 4$
$y = x - 3 + 4$
$y = x + 1$, which is the same equation.

41. (a) $k = 2$ **(b)** $k = -2$

43. 5.97 atmospheres ($k = 0.0994$)

45. (a) $y = 2216.2x - 4387470.6$
(b) 2216.2; it represents the approximate rate of increase in earnings in dollars per year.
(c)



[1995, 2005] by [40000, 50000]

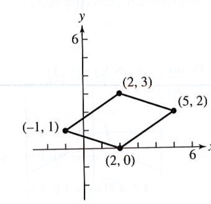
(d) about \$62,659

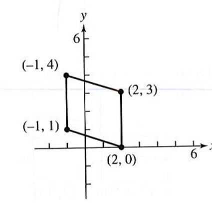
47. False. A vertical line has no slope.

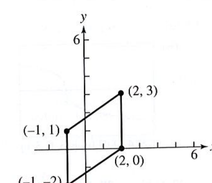
49. A **51.** D

53. (a) $y = 5980x - 11{,}810{,}220$
(b) The rate at which the median price is increasing in dollars per year
(c) $y = 21650x - 43{,}105{,}030$
(d) South: \$5,980 per year, West: \$21,650 per year; more rapidly in the West

55. The coordinates of the three missing vertices are $(5, 2)$, $(-1, 4)$ and $(-1, -2)$.







57. $y = -\frac{3}{4}(x - 3) + 4$ or $y = -\frac{3}{4}x + \frac{25}{4}$

Section 1.2

Quick Review 1.2

1. $[-2, \infty)$ **3.** $[-1, 7]$ **5.** $(-4, 4)$

7. Translate the graph of f 2 units left and 3 units downward.

9. (a) $x = -3, 3$ **(b)** No real solution

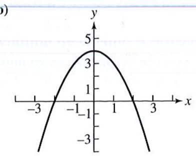
11. (a) $x = 9$ **(b)** $x = -6$

Exercises 1.2

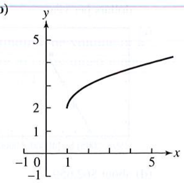
1. (a) $A(d) = \pi\left(\frac{d}{2}\right)^2$ **(b)** $A(4) = 4\pi$ in^2

3. (a) $S(e) = 6e^2$ **(b)** $S(5) = 150$ ft^2

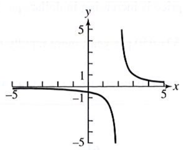
5. (a) $(-\infty, \infty)$; $(-\infty, 4]$
(b)



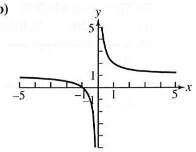
7. (a) $[1, \infty)$; $[2, \infty)$
(b)



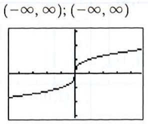
9. (a) $(-\infty, 2) \cup (2, \infty)$; $(-\infty, 0) \cup (0, \infty)$
(b)



11. (a) $(-\infty, 0) \cup (0, \infty)$; $(-\infty, 1) \cup (1, \infty)$
(b)

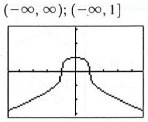


13. (a) $(-\infty, \infty)$; $(-\infty, \infty)$
(b)



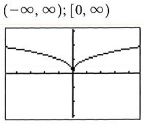
[−4.7, 4.7] by [−3.1, 3.1]

15. (a) $(-\infty, \infty)$; $(-\infty, 1]$
(b)



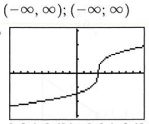
[−4.7, 4.7] by [−3.1, 3.1]

17. (a) $(-\infty, \infty)$; $[0, \infty)$
(b)



[−4.7, 4.7] by [−3.1, 3.1]

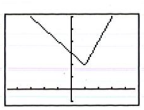
19. (a) $(-\infty, \infty)$; $(-\infty; \infty)$
(b)



[−9.4, 9.4] by [−3.1, 3.1]

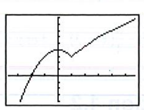
21. Even **23.** Neither **25.** Even **27.** Odd **29.** Neither

31.



[−4.7, 4.7] by [−1, 6]

33.



[−3.7, 5.7] by [−4, 9]

35. Because if the vertical line test holds, then for each x-coordinate, there is at most one y-coordinate giving a point on the curve. This y-coordinate would correspond to the value assigned to the x-coordinate. Since there's only one y-coordinate, the assignment would be unique.

37. No **39.** Yes

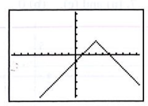
41. $f(x) = \begin{cases} x, & 0 \le x \le 1 \\ 2 - x, & 1 < x \le 2 \end{cases}$

43. $f(x) = \begin{cases} 2 - x, & 0 < x \le 2 \\ \frac{5}{3} - \frac{x}{3}, & 2 < x \le 5 \end{cases}$

45. $f(x) = \begin{cases} -x, & -1 \le x < 0 \\ 1, & 0 < x \le 1 \\ \frac{3}{2} - \frac{x}{2}, & 1 < x < 3 \end{cases}$

47. $f(x) = \begin{cases} 0, & 0 \le x \le \frac{T}{2} \\ \frac{2}{T}x - 1, & \frac{T}{2} < x \le T \end{cases}$

49. (a)



[−9.4, 9.4] by [−6.2, 6.2]

(b) All reals **(c)** $(-\infty, 2]$

51. (a) $x^2 + 2$ **(b)** $x^2 + 10x + 22$ **(c)** 2 **(d)** 22 **(e)** −2 **(f)** $x + 10$

53. (a) $g(x) = x^2$ **(b)** $g(x) = \frac{1}{x - 1}$ **(c)** $f(x) = \frac{1}{x}$ **(d)** $f(x) = x^2$

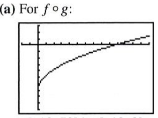
55. (a) Because the circumference of the original circle was 8π and a piece of length x was removed. **(b)** $r = \frac{8\pi - x}{2\pi} = 4 - \frac{x}{2\pi}$

(c) $h = \sqrt{16 - r^2} = \frac{\sqrt{16\pi x - x^2}}{2\pi}$

(d) $V = \frac{1}{3}\pi r^2 h = \frac{(8\pi - x)^2\sqrt{16\pi x - x^2}}{24\pi^2}$

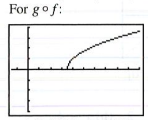
57. False. $f(-x) \neq f(x)$ **59.** B **61.** D

63. (a) For $f \circ g$:



[−10, 70] by [−10, 3]

Domain: $[0, \infty)$; Range: $[-7, \infty)$
For $g \circ f$:

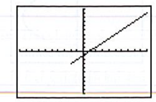


[−3, 20] by [−4, 4]

Domain: $[7, \infty)$; Range: $[0, \infty)$

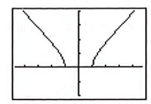
(b) $(f \circ g)(x) = \sqrt{x} - 7$; $(g \circ f)(x) = \sqrt{x - 7}$

65. (a) For $f \circ g$:



[−10, 10] by [−10, 10]

Domain: $[-2, \infty)$; Range: $[-3, \infty)$
For $g \circ f$:

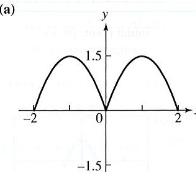


[−4.7, 4.7] by [−2, 4]

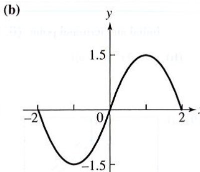
Domain: $(-\infty, -1] \cup [1, \infty)$; Range: $[0, \infty)$

(b) $(f \circ g)(x) = (\sqrt{x + 2})^2 - 3 = x - 1, x \ge -2$
$(g \circ f)(x) = \sqrt{x^2 - 1}$

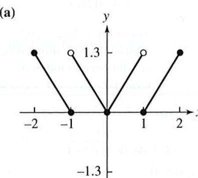
67. (a)



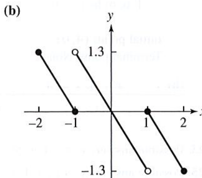
(b)



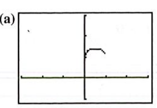
69. (a)



(b)



71. (a)



[−3, 3] by [−1, 3]

(b) Domain of y_1: $[0, \infty)$
Domain of y_2: $(-\infty, 1]$
Domain of y_3: $[0, 1]$

(c) The results for $y_1 - y_2$, $y_2 - y_1$, and $y_1 \cdot y_2$ are the same as for $y_1 + y_2$ above.

Domain of $\frac{y_1}{y_2}$: $[0, 1)$ Domain of $\frac{y_2}{y_1}$: $(0, 1]$

(d) The domain of a sum, difference, or product of two functions is the intersection of their domains.
The domain of a quotient of two functions is the intersection of their domains with any zeros of the denominator removed.

Section 1.3

Quick Review 1.3

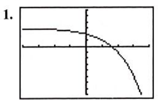
1. 2.924 **3.** 0.192

5. 1.8882 **7.** \$630.58

9. $x^{-18}y^{-5} = \frac{1}{x^{18}y^5}$

Exercises 1.3

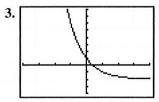
1.



[−4, 4] by [−8, 6]

Domain: All reals Range: $(-\infty, 3)$

3.



[−4, 4] by [−4, 8]

Domain: All reals Range: $(-2, \infty)$

5. 3^{4x} **7.** 2^{-6x} **9.** ≈ 2.322 **11.** ≈ -0.631

13. (a) **15.** (e) **17.** (b)

19. (a) 1.032, 1.041, 1.034, 1.034, 1.029

(b) One possibility is $2168(1.034)^n$.

(c) 3348 thousand, or 3,348,000

21. After 19 years

23. (a) $A(t) = 6.6\left(\frac{1}{2}\right)^{t/14}$

(b) About 38.1145 days later

25. ≈ 11.433 years **27.** ≈ 11.090 years

29. ≈ 19.108 years **31.** $2^{48} \approx 2.815 \times 10^{14}$

33.

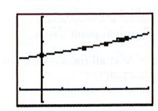
x	y	Δy
1	−1	
2	1	2
3	3	2
4	5	2

35.

x	y	Δy
1	1	
2	4	3
3	9	5
4	16	7

37. Since $\Delta x = 1$, the corresponding value of Δy is equal to the slope of the line. If the changes in x are constant for a linear function, then the corresponding changes in y are constant as well.

39. (a) $y = 14153.84(1.01963)^x$



[−5, 25] by [−5000, 30000]

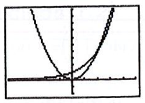
(b) Estimate: 22,133,000; the estimate exceeds the actual by 14,000.

(c) ≈ 0.020 or 2%

41. False. It is positive 1/9

43. D **45.** B

47. (a)



[−5, 5] by [−2, 10]

In this window, it appears they cross twice, although a third crossing off-screen appears likely.

(b)

x	change in $Y1$	change in $Y2$
1		
	3	2
2		
	5	4
3		
	7	8
4		

(c) $x = -0.7667, x = 2, x = 4$ **(d)** $(-0.7667, 2) \cup (4, \infty)$

49. $a = 0.5, k = 3$

Quick Quiz (Sections 1.1–1.3)

1. C **3.** E

Section 1.4

Quick Review 1.4

1. $y = -\frac{5}{3}x + \frac{29}{3}$ **3.** $x = 2$

5. x-intercepts: $x = -4$ and $x = 4$ y-intercepts: none

7. (a) Yes **(b)** No **(c)** Yes

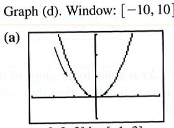
9. (a) $t = \frac{-2x - 5}{3}$ **(b)** $t = \frac{3y + 1}{2}$

Exercises 1.4

1. Graph (c). Window: $[-4, 4]$ by $[-3, 3]$, $0 \le t \le 2\pi$

3. Graph (d). Window: $[-10, 10]$ by $[-10, 10]$, $0 \le t \le 2\pi$

5. (a)

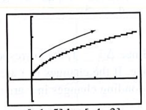


[−3, 3] by [−1, 3]

No initial or terminal point

(b) $y = x^2$; all

7. (a)

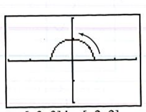


[−1, 5] by [−1, 3]

Initial point: $(0, 0)$
Terminal point: None

(b) $y = \sqrt{x}$; all (or $x = y^2$; upper half)

9. (a)

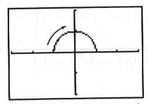


[−3, 3] by [−2, 2]

Initial point: $(1, 0)$
Terminal point: $(-1, 0)$

(b) $x^2 + y^2 = 1$; upper half (or $y = \sqrt{1 - x^2}$; all)

11. (a)

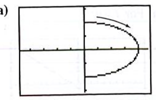


[−3, 3] by [−2, 2]

Initial point: $(-1, 0)$
Terminal point: $(0, 1)$

(b) $x^2 + y^2 = 1$; upper half (or $y = \sqrt{1 - x^2}$; all)

13. (a)

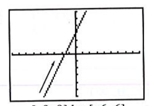


[−4.7, 4.7] by [−3.1, 3.1]

Initial point: $(0, 2)$
Terminal point: $(0, -2)$

(b) $\left(\frac{x}{4}\right)^2 + \left(\frac{y}{2}\right)^2 = 1$; right half (or $x = 2\sqrt{4 - y^2}$; all)

15. (a)

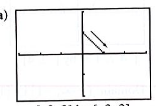


[−9, 9] by [−6, 6]

Initial and terminal point: $(0, 5)$

(b) $y = 2x + 3$; all

17. (a)

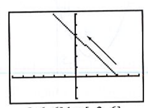


[−3, 3] by [−2, 2]

Initial point: $(0, 1)$
Terminal point: $(1, 0)$

(b) $y = -x + 1$; $(0, 1)$ to $(1, 0)$

19. (a)

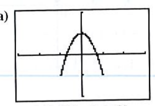


[−6, 6] by [−2, 6]

Initial point: $(4, 0)$
Terminal point: None

(b) $y = -x + 4; x \le 4$

21. (a)



[−3, 3] by [−2, 2]

The curve is traced and retraced in both directions, and there is no initial or terminal point.

(b) $y = -2x^2 + 1; -1 \le x \le 1$

23. Possible answer: $x = -1 + 5t, y = -3 + 4t, 0 \le t \le 1$

25. Possible answer: $x = t^2 + 1, y = t, t \le 0$

27. Possible answer: $x = 2 - 3t, y = 3 - 4t, t \ge 0$

29. $1 < t < 3$ **31.** $-5 \le t < -3$

33. Possible answer: $x = t, y = t^2 + 2t + 2, t > 0$

35. Possible answers:
(a) $x = a\cos t, y = -a\sin t, 0 \le t \le 2\pi$
(b) $x = a\cos t, y = a\sin t, 0 \le t \le 2\pi$
(c) $x = a\cos t, y = -a\sin t, 0 \le t \le 4\pi$
(d) $x = a\cos t, y = a\sin t, 0 \le t \le 4\pi$

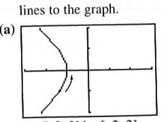
37. False. It is an ellipse.

39. D **41.** A

43. (a) The resulting graph appears to be the right half of a hyperbola in the first and fourth quadrants. The parameter a determines the x-intercept. The parameter b determines the shape of the hyperbola. If b is smaller, the graph has less steep slopes and appears "sharper." If b is larger, the slopes are steeper and the graph appears more "blunt."
(b) This appears to be the left half of the same hyperbola.
(c) Because both sec t and tan t are discontinuous at these points. This might cause the grapher to include extraneous lines (the asymptotes to the hyperbola) in its graph.

(d) $\left(\frac{x}{a}\right)^2 - \left(\frac{y}{b}\right)^2 = (\sec t)^2 - (\tan t)^2 = 1$ by a standard trigonometric identity.
(e) This changes the orientation of the hyperbola. In this case, b determines the y-intercept of the hyperbola, and a determines the shape. The parameter interval $\left(-\frac{\pi}{2}, \frac{\pi}{2}\right)$ gives the upper half of the hyperbola. The parameter interval $\left(\frac{\pi}{2}, \frac{3\pi}{2}\right)$ gives the lower half. The same values of t cause discontinuities and may add extraneous lines to the graph.

45. (a)



[−3, 3] by [−2, 2]

No initial or terminal point

(b) $x^2 - y^2 = 1$; left branch (or $x = -\sqrt{y^2 + 1}$; all)

47. $x = 2\cot t, y = 2\sin^2 t, 0 < t < \pi$

Section 1.5

Quick Review 1.5

1. 1 **3.** $x^{2/3}$

5. Possible answer: $x = t, y = \frac{1}{t - 1}, t \ge 2$

7. $(4, 5)$

9. (a) $(1.58, 3)$ **(b)** No intersection

Exercises 1.5

1. No **3.** Yes **5.** Yes **7.** Yes **9.** No **11.** No

13. $f^{-1}(x) = \frac{x - 3}{2}$

15. $f^{-1}(x) = (x + 1)^{1/3}$ or $\sqrt[3]{x + 1}$

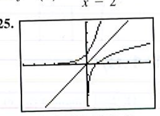
17. $f^{-1}(x) = -x^{1/2}$ or $-\sqrt{x}$

19. $f^{-1}(x) = 2 - (-x)^{1/2}$ or $2 - \sqrt{-x}$

21. $f^{-1}(x) = \frac{1}{x^{1/2}}$ or $\frac{1}{\sqrt{x}}$

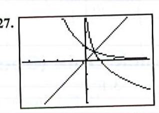
23. $f^{-1}(x) = \frac{1 - 3x}{x - 2}$

25.



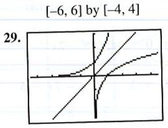
[−6, 6] by [−4, 4]

27.



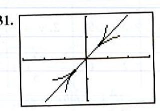
[−4.5, 4.5] by [−3, 3]

29.



[−4.5, 4.5] by [−3, 3]

31.



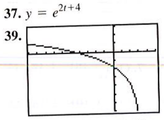
[−3, 3] by [−2, 2]

33. $t = \frac{\ln 2}{\ln 1.045} \approx 15.75$

35. $x = \ln\left(\frac{3 \pm \sqrt{5}}{2}\right) \approx -0.96$ or 0.96

37. $y = e^{2t+4}$

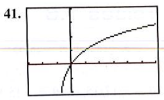
39.



[−10, 5] by [−7, 3]

Domain: $(-\infty, 3)$;
Range: all reals

41.



[−3, 6] by [−2, 4]

Domain: $(-1, \infty)$;
Range: all reals

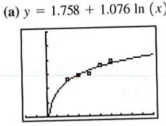
43. $f^{-1}(x) = \log_2\left(\frac{x}{100 - x}\right)$

45. (a)
$$\begin{aligned} f(f(x)) &= \sqrt{1 - (f(x))^2} \\ &= \sqrt{1 - (1 - x^2)} \\ &= \sqrt{x^2} \\ &= x, \text{ since } x \ge 0 \end{aligned}$$

(b) $f(f(x)) = f\left(\frac{1}{x}\right) = \frac{1}{1/x} = x$ for all $x \ne 0$

47. About 14.936 years. (If the interest is only paid annually, it will take 15 years.)

49. (a) $y = 1.758 + 1.076 \ln(x)$



[−2, 10] by [0, 6]

(b) 4 trillion cubic feet
(c) Sometime during 2009

51. (a) Suppose that $f(x_1) = f(x_2)$. Then $mx_1 + b = mx_2 + b$, which gives $x_1 = x_2$ since $m \ne 0$.
(b) $f^{-1}(x) = \frac{x - b}{m}$; the slopes are reciprocals.
(c) They are also parallel lines with nonzero slope.
(d) They are also perpendicular lines with nonzero.

53. False. Consider $f(x) = x^2$, $g(x) = \sqrt{x}$. Notice that $(f \circ g)(x) = x$ but f is not one-to-one.

55. A **57.** B

59. If the graph of $f(x)$ passes the horizontal line test, so will the graph of $g(x) = -f(x)$ since it's the same graph reflected about the x-axis.

61. (a) Domain: All reals
Range: If $a > 0$, then (d, ∞)
If $a < 0$, then $(-\infty, d)$
(b) Domain: (c, ∞)
Range: All reals

Section 1.6

Quick Review 1.6

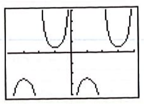
1. $60°$ **3.** $-\frac{2\pi}{9}$ **5.** $x \approx 0.6435, x \approx 2.4981$

7. $x \approx 0.7854 \left(\text{or } \frac{\pi}{4}\right), x \approx 3.9270 \left(\text{or } \frac{5\pi}{4}\right)$

9. $f(-x) = (-x)^3 - 3(-x) = -x^3 + 3x$
$= -(x^3 - 3x) = -f(x)$
The graph is symmetric about the origin because if a point (a, b) is on the graph, then so is the point $(-a, -b)$.

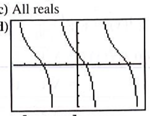
Exercises 1.6

1. $\frac{5\pi}{4}$ **3.** $\frac{1}{2}$ radian or $\approx 28.65°$ **5.** Even **7.** Odd
9. $\sin\theta = 8/17$, $\tan\theta = -8/15$, $\csc\theta = 17/8$, $\sec\theta = -17/15$, $\cot\theta = -15/8$
11. (a) $\frac{2\pi}{3}$
(b) $x \neq \frac{k\pi}{3}$, for integers k
(c) $(-\infty, -5] \cup [1, \infty)$
(d)



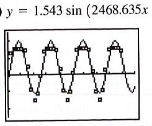
$\left[-\frac{2\pi}{3}, \frac{2\pi}{3}\right]$ by $[-8, 8]$

13. (a) $\frac{\pi}{3}$
(b) $x \neq \frac{k\pi}{6}$, for odd integers k
(c) All reals
(d)



$\left[-\frac{\pi}{2}, \frac{\pi}{2}\right]$ by $[-8, 8]$

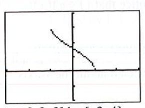
15. Possible answers are:
(a) $[0, 4\pi]$ by $[-3, 3]$ **(b)** $[0, 4\pi]$ by $[-3, 3]$
(c) $[0, 2\pi]$ by $[-3, 3]$
17. (a) π **(b)** 1.5 **(c)** $[-2\pi, 2\pi]$ by $[-2, 2]$
19. (a) π **(b)** 3 **(c)** $[-2\pi, 2\pi]$ by $[-4, 4]$
21. (a) 6 **(b)** 4 **(c)** $[-3, 3]$ by $[-5, 5]$
23. (a) $y = 1.543 \sin(2468.635x - 0.494) + 0.438$



[0, 0.01]by [−2.5, 2.5]

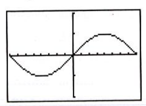
(b) Frequency = 392.9, so it must be a "G."

25. The portion of the curve $y = \cos x$ between $0 \le x \le \pi$ passes the horizontal line test so it is one-to-one.



[−3, 3] by [−2, 4]

27. $\frac{\pi}{6}$ radian or 30° **29.** ≈ -1.3734 radians or $-78.6901°$
31. $x \approx 1.190$ and $x \approx 4.332$ **33.** $x = \frac{\pi}{6}$ and $x = \frac{5\pi}{6}$
35. $x = \frac{7\pi}{6} + 2k\pi$ and $x = \frac{11\pi}{6} + 2k\pi$, k any integer
37. $\cos\theta = \frac{15}{17}$ $\sin\theta = \frac{8}{17}$ $\tan\theta = \frac{8}{15}$
$\sec\theta = \frac{17}{15}$ $\csc\theta = \frac{17}{8}$ $\cot\theta = \frac{15}{8}$
39. $\cos\theta = -\frac{3}{5}$ $\sin\theta = \frac{4}{5}$ $\tan\theta = -\frac{4}{3}$
$\sec\theta = -\frac{5}{3}$ $\csc\theta = \frac{5}{4}$ $\cot\theta = -\frac{3}{4}$
41. $\frac{\sqrt{72}}{11} \approx 0.771$
43. (a) 37 **(b)** 365 **(c)** 101 **(d)** 25
(e) $f(x) = 37 \sin\left[\frac{2\pi}{365}(x - 101)\right] + 25$
45. (a) $\cot(-x) = \frac{\cos(-x)}{\sin(-x)} = \frac{\cos(x)}{-\sin(x)} = -\cot(x)$
(b) Assume that f is even and g is odd.
Then $\frac{f(-x)}{g(-x)} = \frac{f(x)}{-g(x)} = -\frac{f(x)}{g(x)}$ so $\frac{f}{g}$ is odd.
The situation is similar for $\frac{g}{f}$.
47. Assume that f is even and g is odd.
Then $f(-x)\,g(-x) = f(x)[-g(x)] = -f(x)g(x)$ so fg is odd.
49. (a) $y \approx 3.0014 \sin(0.9996x + 2.0012) + 2.9999$
(b) $y = 3 \sin(x + 2) + 3$
51. False. The amplitude is 1/2.
53. B **55.** A
57. (a) $\sqrt{2} \sin\left(ax + \frac{\pi}{4}\right)$ **(b)** See part (a).
(c) It works.
(d) $\sin\left(ax + \frac{\pi}{4}\right)$
$= \sin(ax) \cdot \frac{1}{\sqrt{2}} + \cos(ax) \cdot \frac{1}{\sqrt{2}}$
$= \frac{1}{\sqrt{2}}(\sin ax + \cos ax)$
So, $\sin(ax) + \cos(ax) = \sqrt{2} \sin\left(ax + \frac{\pi}{4}\right)$.
59. Since $\sin(x)$ has period 2π, $(\sin(x + 2\pi))^3 = (\sin(x))^3$. This function has period 2π. A graph shows that no smaller number works for the period.
61. One possible graph:



$\left[-\frac{\pi}{60}, \frac{\pi}{60}\right]$ by $[-2, 2]$

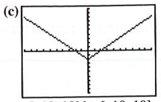
Quick Quiz (Sections 1.4–1.6)

1. C **3.** E

Review Exercises

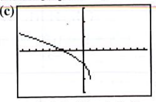
1. $y = 3x - 9$ **2.** $y = -\frac{1}{2}x + \frac{3}{2}$ **3.** $x = 0$ **4.** $y = -2x$
5. $y = 2$ **6.** $y = -\frac{2}{5}x + \frac{21}{5}$ **7.** $y = -3x + 3$ **8.** $y = 2x - 5$
9. $y = -\frac{4}{3}x - \frac{20}{3}$ **10.** $y = -\frac{5}{3}x - \frac{19}{3}$ **11.** $y = \frac{2}{3}x + \frac{8}{3}$

12. $y = \frac{5}{3}x - 5$ **13.** $y = -\frac{1}{2}x + 3$ **14.** $y = -\frac{2}{7}x - \frac{6}{7}$
15. Origin **16.** y-axis **17.** Neither **18.** y-axis
19. Even **20.** Odd **21.** Even **22.** Odd **23.** Odd
24. Neither **25.** Neither **26.** Even
27. (a) Domain: all reals
(b) Range: $[-2, \infty)$
(c)



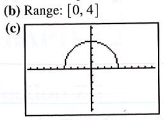
[−10, 10] by [−10, 10]

28. (a) Domain: $(-\infty\ 1]$
(b) Range $[-2, \infty)$
(c)



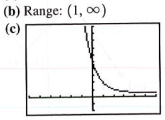
[−9.4, 9.4] by [−3, 3]

29. (a) Domain: $[-4, 4]$
(b) Range: $[0, 4]$
(c)



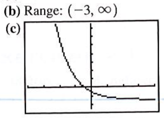
[−9.4, 9.4] by [−6.2, 6.2]

30. (a) Domain: all reals
(b) Range: $(1, \infty)$
(c)



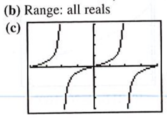
[−6, 6] by [−4, 20]

31. (a) Domain: all reals
(b) Range: $(-3, \infty)$
(c)



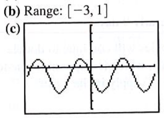
[−4, 4] by [−5, 15]

32. (a) Domain: $x \neq \frac{k\pi}{4}$, for odd integers k
(b) Range: all reals
(c)



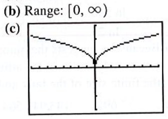
$\left[-\frac{\pi}{2}, \frac{\pi}{2}\right]$ by $[-8, 8]$

33. (a) Domain: all reals
(b) Range: $[-3, 1]$
(c)



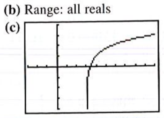
$[-\pi, \pi]$ by $[-5, 5]$

34. (a) Domain: all reals
(b) Range: $[0, \infty)$
(c)



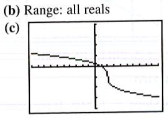
[−8, 8] by [−3, 3]

35. (a) Domain: $(3, \infty)$
(b) Range: all reals
(c)



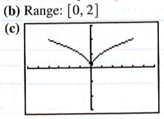
[−3, 10] by [−4, 4]

36. (a) Domain: all reals
(b) Range: all reals
(c)



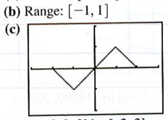
[−10, 10] by [−4, 4]

37. (a) Domain: $[-4, 4]$
(b) Range: $[0, 2]$
(c)



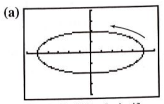
[−6, 6] by [−3, 3]

38. (a) Domain: $[-2, 2]$
(b) Range: $[-1, 1]$
(c)



[−3, 3] by [−2, 2]

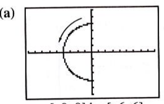
39. $f(x) = \begin{cases} 1 - x, & 0 \le x < 1 \\ 2 - x, & 1 \le x \le 2 \end{cases}$
40. $f(x) = \begin{cases} \frac{5x}{2}, & 0 \le x < 2 \\ -\frac{5}{2}x + 10, & 2 \le x \le 4 \end{cases}$
41. (a) 1 **(b)** $\frac{1}{\sqrt{2.5}}\left(= \sqrt{\frac{2}{5}}\right)$ **(c)** $x, x \neq 0$ **(d)** $\frac{1}{\sqrt{1/\sqrt{x+2}+2}}$
42. (a) 2 **(b)** 1 **(c)** x **(d)** $\sqrt[3]{\sqrt[3]{x+1}+1}$
43. (a) $(f \circ g)(x) = -x, x \ge -2$
$(g \circ f)(x) = \sqrt{4 - x^2}$
(b) Domain $(f \circ g)$: $[-2, \infty)$
Domain $(g \circ f)$: $[-2, 2]$
(c) Range $(f \circ g)$: $(-\infty, 2]$
Range $(g \circ f)$: $[0, 2]$
44. (a) $(f \circ g)(x) = \sqrt[4]{1 - x}$
$(g \circ f)(x) = \sqrt{1 - \sqrt{x}}$
(b) Domain $(f \circ g)$: $(-\infty, 1]$
Domain $(g \circ f)$: $[0, 1]$
(c) Range $(f \circ g)$: $[0, \infty)$
Range $(g \circ f)$: $[0, 1]$
45. (a)



[−6, 6] by [−4, 4]

Initial point: (5, 0)
Terminal point: (5, 0)
(b) $\left(\frac{x}{5}\right)^2 + \left(\frac{y}{2}\right)^2 = 1$; all

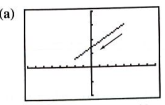
46. (a)



[−9, 9] by [−6, 6]

Initial point: (0, 4)
Terminal point: (0, −4)
(b) $x^2 + y^2 = 16$; left half

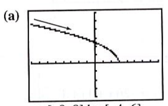
47. (a)



[−8, 8] by [−10, 20]

Initial point: (4, 15)
Terminal point: (−2, 3)
(b) $y = 2x + 7$; from (4, 15) to (−2, 3)

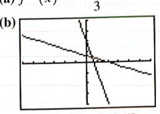
48. (a)



[−8, 8] by [−4, 6]

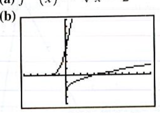
Initial point: None
Terminal point: (3, 0)
(b) $y = \sqrt{6 - 2x}$; all

49. Possible answer: $x = -2 + 6t, y = 5 - 2t, 0 \le t \le 1$
50. Possible answer: $x = -3 + 7t, y = -2 + t, -\infty < t < \infty$
51. Possible answer: $x = 2 - 3t, y = 5 - 5t, 0 \le t$
52. Possible answer: $x = t, y = t(t - 4), t \le 2$
53. (a) $f^{-1}(x) = \frac{2 - x}{3}$
(b)



[−6, 6] by [−4, 4]

54. (a) $f^{-1}(x) = \sqrt{x} - 2$
(b)



[−6, 12] by [−4, 8]

55. ≈ 0.6435 radians or $36.8699°$

56. ≈ -1.1607 radians or $-66.5014°$

57. $\cos\theta = \frac{3}{7}$ $\sin\theta = \frac{\sqrt{40}}{7}$ $\tan\theta = \frac{\sqrt{40}}{3}$

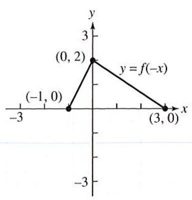
$\sec\theta = \frac{7}{3}$ $\csc\theta = \frac{7}{\sqrt{40}}$ $\cot\theta = \frac{3}{\sqrt{40}}$

58. (a) $x \approx 3.3430$ and $x \approx 6.0818$

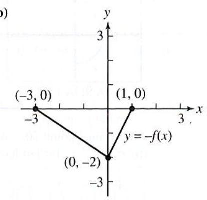
(b) $x \approx 3.3430 + 2k\pi$ and $x \approx 6.0818 + 2k\pi$, k any integer

59. $x = -5\ln 4$

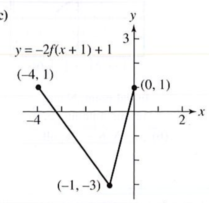
60. (a)



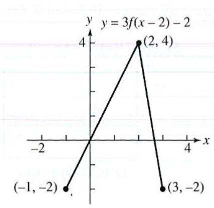
(b)



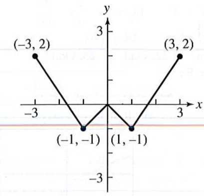
(c)



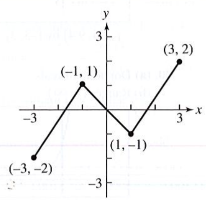
(d)



61. (a)



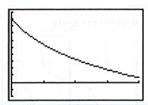
(b)



62. (a) $V = 100{,}000 - 10{,}000x$, $0 \le x \le 10$ **(b)** After 4.5 years

63. (a) 90 units **(b)** $90 - 52\ln 3 \approx 32.8722$ units

(c)



[0, 4] by [–20, 100]

64. After $\frac{\ln(10/3)}{\ln 1.08} \approx 15.6439$ years

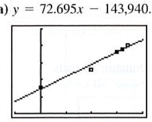
(If the bank only pays interest at the end of the year, it will take 16 years.)

65. (a) $N = 4 \cdot 2^t$ **(b)** 4 days: 64; 1 week: 512

(c) After $\frac{\ln 500}{\ln 2} \approx 8.9658$ days, or after nearly 9 days

(d) Because it suggests the number of guppies will continue to double indefinitely and become arbitrarily large, which is impossible due to the finite size of the tank and the oxygen supply in the water.

66. (a) $y = 72.695x - 143{,}940.564$

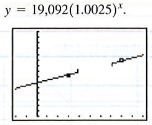


[–5, 20] by [0, 2500]

(b) 2103

(c) Slope = 72.695. It represents the number of doctoral degrees earned per year.

67. (a) $y = 19{,}092(1.0025)^x$.



[–2, 10] by [18500, 20000]

(b) 19,526 thousand or 19,526,000

(c) 0.0025 or 0.25%.

68. (a) $m = -1$ **(b)** $y = -x - 1$ **(c)** $y = x + 3$ **(d)** 2

69. (a) $(2, \infty)$ **(b)** $(-\infty, \infty)$ **(c)** $x = 2 + e \approx 4.718$

(d) $f^{-1}(x) = 2 + e^{1-x}$

(e)
$$\begin{aligned}(f \circ g^{-1})(x) = f(f^{-1}(x)) = f(2 + e^{1-x}) &= 1 - \ln(2 + e^{1-x} - 2)\\ &= 1 - \ln(e^{1-x})\\ &= 1 - (1 - x)\\ &= x\end{aligned}$$
$$\begin{aligned}(f^{-1} \circ g)(x) = f^{-1}(f(x)) = f^{-1}(1 - \ln(x - 2)) &= 2 + e^{1-(1-\ln(x-2))}\\ &= 2 + e^{\ln(x-2)}\\ &= 2 + (x - 2)\\ &= x\end{aligned}$$

70. (a) $(-\infty, \infty)$ **(b)** $[-2, 4]$ **(c)** π **(d)** Even **(e)** $x \approx 2.526$

CHAPTER 2

Section 2.1

Quick Review 2.1

1. 0 **3.** 0 **5.** $-4 < x < 4$

7. $-1 < x < 5$ **9.** $x - 6$

Exercises 2.1

1. 48 ft/sec **3.** 96 ft/sec

5. $2c^3 - 3c^2 + c - 1$

7. $-\frac{3}{2}$ **9.** -15 **11.** 0 **13.** 4

15. (a)

x	-0.1	-0.01	-0.001	-0.0001
$f(x)$	1.566667	1.959697	1.995997	1.999600

(b)

x	0.1	0.01	0.001	0.0001
$f(x)$	2.372727	2.039703	2.003997	2.000400

The limit appears to be 2.

17. (a)

x	-0.1	-0.01	-0.001	-0.0001
$f(x)$	-0.054402	-0.005064	-0.000827	-0.000031

(b)

x	0.1	0.01	0.001	0.0001
$f(x)$	-0.054402	-0.005064	-0.000827	-0.000031

The limit appears to be 0.

19. (a)

x	-0.1	-0.01	-0.001	-0.0001
$f(x)$	2.0567	2.2763	2.2999	2.3023

(b)

x	0.1	0.01	0.001	0.0001
$f(x)$	2.5893	2.3293	2.3052	2.3029

The limit appears to be approximately 2.3.

21. Expression not defined at $x = -2$. There is no limit.

23. Expression not defined at $x = 0$. There is no limit.

25. $\frac{1}{2}$ **27.** $-\frac{1}{2}$ **29.** 12 **31.** -1 **33.** 0

35. Answers will vary. One possible graph is given by the window [–4.7, 4.7] by [–15, 15] with Xscl = 1 and Yscl = 5.

37. 0 **39.** 0 **41.** 1

43. (a) True **(b)** True

(c) False **(d)** True

(e) True **(f)** True

(g) False **(h)** False

(i) False **(j)** False

45. (a) 3 **(b)** -2

(c) No limit **(d)** 1

47. (a) -4 **(b)** -4

(c) -4 **(d)** -4

49. (a) 4 **(b)** -3

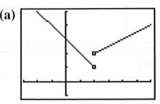
(c) No limit **(d)** 4

51. (c) **53.** (d)

55. (a) 6 **(b)** 0

(c) 9 **(d)** -3

57. (a)

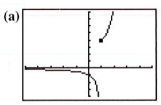


[–3, 6] by [–1, 5]

(b) Right-hand: 2 Left-hand: 1

(c) No, because the two one-sided limits are different

59. (a)

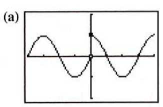


[–5, 5] by [–4, 8]

(b) Right-hand: 4 Left-hand: no limit

(c) No, because the left-hand limit doesn't exist

61. (a)

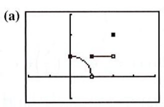


[-2π, 2π] by [–2, 2]

(b) $(-2\pi, 0) \cup (0, 2\pi)$

(c) $c = 2\pi$ **(d)** $c = -2\pi$

63. (a)



[–2, 4] by [–1, 3]

(b) $(0, 1) \cup (1, 2)$ **(c)** $c = 2$

(d) $c = 0$

65. 0

67. 0

69. (a) 14.7 m/sec

(b) 29.4 m/sec

71. True. Definition of limit.

73. C **75.** E

77. (a) Because the right-hand limit at zero depends only on the values of the function for positive x-values near zero

(b) Use: area of triangle $= \left(\frac{1}{2}\right)$(base)(height)

area of circular sector $= \frac{(\text{angle})(\text{radius})^2}{2}$

(c) This is how the areas of the three regions compare.

(d) Multiply by 2 and divide by $\sin\theta$.

(e) Take reciprocals, remembering that all of the values involved are positive.

(f) The limits for $\cos\theta$ and 1 are both equal to 1. Since $\frac{\sin\theta}{\theta}$ is between them, it must also have a limit of 1.